[Document Type] Patent Specification

[Title of the Invention] Time Measuring Device and Control Method for a Time Measuring Device

[Claims]

[Claim 1]

A time measuring device, comprising:

an antenna;

a communication unit configured to communicate with an external communication device through the antenna; and

a time indicating unit configured to indicate time information by means of a mechanical mechanism using a piezoelectric actuator as a drive source.

[Claim 2]

The time measuring device recited in claim 1, wherein

the communication unit has a receiver configured to receive time of day information from an external source through the antenna once per prescribed period and a current time of day counter configured to update the current time of day information successively based on a time of day corresponding to the time of day information received by the receiver; and

the time indicating unit is configured to indicate time information based on the current

time of day information by means of the mechanical mechanism using the piezoelectric actuator as a drive source.

[Claim 3]

The time measuring device recited in claim 1 or 2, wherein

the piezoelectric actuator is configured to rotationally drive a rotor by moving in an elliptical pattern achieved by combining a longitudinal vibration and a bending vibration.

[Claim 4]

An analog electronic timepiece recited in claim 1 or 2, wherein

the piezoelectric actuator is provided with the following: a vibrating plate made by laminating a plate-like piezoelectric element and a reinforcing plate together; a fixing part serving to fix the vibrating plate to a support body; and an abutting part provided on a lengthwise-facing end of the vibrating plate, the piezoelectric actuator being arranged and configured such that when a drive signal is supplied to the piezoelectric element, the piezoelectric element elongates and contracts in such a manner that the vibrating plate undergoes a vibration in which it elongates and contracts in the lengthwise direction and a vibration oriented in a direction crosswise with respect to the lengthwise direction, said vibrations causing the abutting part to be displaced in such a manner that a rotor is rotationally driven.

[Claim 5]

The time measuring device recited in claim 1 or 2, wherein

the time indicating unit is provided with an indicator needle driving actuator configured to drive an indicator needle that serves to indicate time information; and

the antenna is arranged in such a position that an orthogonal projection thereof onto a plane that is perpendicular to the thickness direction of the time measuring device does not overlap with an orthogonal projection of the indicator needle driving piezoelectric actuator onto the same plane and the antenna is separated from the indicator needle piezoelectric actuator by a prescribed distance in a direction perpendicular to said thickness direction.

[Claim 6]

The time measuring device recited in claim 1 or 2, wherein

the time indicating unit is provided with an indicator needle driving actuator configured to drive an indicator needle that serves to indicate time information; and

the antenna is arranged in such a position that at least a portion of an orthogonal projection thereof onto a plane that is perpendicular to the thickness direction of the time measuring device overlaps with an orthogonal projection of the indicator needle driving piezoelectric actuator onto the same plane and the antenna is separated from the indicator needle piezoelectric actuator by a prescribed distance in said thickness direction.

[Claim 7]

A control method for a time measuring device, comprising:

a time indicating process in which time information is indicated by means of a mechanical mechanism using a piezoelectric actuator as a drive source;

a communication process executed in parallel with the time indicating process in which communication is conducted with respect to an external communication device through an antenna.

[Claim 8]

A control method for a time measuring device, comprising:

a receiving process in which time of day information is received from an external source through the antenna once per prescribed period;

a current time of day counting process executed in parallel with the receiving process in which the current time of day information is successively updated based on a time of day corresponding to the time of day information already received; and

a time indicating process in which time information is indicated based on the current time of day information by means of a mechanical mechanism using a piezoelectric actuator as a drive source.

[Detailed Description of the Invention]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to a time measuring device and a control method for a time measuring device. More particularly, the present invention relates to a time measuring device configured as a radio controlled timepiece and a control method for such a time measuring device.

[PRIOR ART]

Radio controlled timepieces configured to receive a standard low frequency radio signal (JG2AS) from an external source once per prescribed period and correct the time of day they indicate based on time of day data carried by the standard low frequency radio signal (JG2AS) have been known for some time.

The time of day data contained in the standard low frequency radio signal used for correcting the indicated time of radio controlled timepieces are transmitted in 60-second cycles (i.e., at a rate of one time of day datum per minute). Each time of day datum includes the number of days from January 1 of the current year to the current date, the current hour, the current minute, etc.

[Patent Document 1]

Examined Japanese Patent Publication No. 3163403

[OBJECT THE INVENTION IS TO ACHIEVE]

In conventional radio controlled timepieces, the time of day data contained in the standard low frequency radio signal cannot be received properly if the stepping motor for driving the indicator needles that indicate the time of day causes electromagnetic noise to occur while the antenna is receiving the standard low frequency radio signal. In short, there is the possibility that the antenna will be unable to receive the standard low frequency radio signal or will receive the signal incorrectly.

In order to resolve this issue, the technology presented in Patent Document 1 provides a circuit for stopping the stepping motor when the antenna is receiving the standard low frequency radio signal, thereby preventing the occurrence of electromagnetic noise caused by driving the stepping motor. The current time of day is corrected after the standard low frequency radio signal is received.

Consequently, with the radio controlled timepiece described in Patent Document 1, the circuitry is complex and the time of day indicated by the timepiece is inaccurate when the standard low frequency radio signal is being received.

The object of the present invention is to provide a time measuring device that has simpler circuitry and can indicate the time of day accurately even when the standard low frequency radio signal is being received, and to provide a control method for such a time

measuring device.

[MEANS OF ACHIEVING THE OBJECT]

In order to achieve the object, the time measuring device is provided with an antenna, a communication unit configured to communicate with an external communication device through the antenna, and a time indicating unit configured to indicate time information by means of a mechanical mechanism using a piezoelectric actuator as a drive source. With this arrangement, the communication unit communicates with the external communication device through the antenna and the time indicating unit indicates the time information by means of the mechanical mechanism (using a piezoelectric actuator as a drive source) either in parallel with or independently of the communication executed by the communication unit.

It is acceptable for the communication unit to have a receiver configured to receive time of day information from an external source through the antenna once per prescribed period and a current time of day counter configured to update the current time of day information successively based on a time of day corresponding to the time of day information received by the receiver and for the time indicating unit to be configured to indicate time information based on the current time of day information by means of the mechanical mechanism using the piezoelectric actuator as a drive source

It is further acceptable for the piezoelectric actuator of the time indicating unit to be configured to rotationally drive a rotor by moving in an elliptical pattern achieved by combining a longitudinal vibration and a bending vibration.

It is further acceptable for the piezoelectric actuator of the time indicating unit to be provided with a vibrating plate made by laminating a plate-like piezoelectric element and a reinforcing plate together, a fixing part serving to fix the vibrating plate to a support body, and an abutting part provided on a lengthwise-facing end of the vibrating plate, the piezoelectric actuator being arranged and configured such that when a drive signal is supplied to the piezoelectric element, the piezoelectric element elongates and contracts in such a manner that the vibrating plate undergoes a vibration in which it elongates and contracts in the lengthwise direction and a vibration oriented in a direction crosswise with respect to the lengthwise direction, said vibrations causing the abutting part to be displaced in such a manner that a rotor is rotationally driven.

It is further acceptable for the time indicating unit to be provided with an indicator needle driving actuator configured to drive an indicator needle that serves to indicate time information and for the antenna to be arranged in such a position that an orthogonal projection thereof onto a plane that is perpendicular to the thickness direction of the time measuring device does not overlap with an orthogonal projection of the indicator needle

driving piezoelectric actuator onto the same plane and the antenna is separated from the indicator needle piezoelectric actuator by a prescribed distance in a direction perpendicular to said thickness direction.

It is further acceptable for the time indicating unit to be provided with an indicator needle driving actuator configured to drive an indicator needle that serves to indicate time information and for the antenna to be arranged in such a position that at least a portion of an orthogonal projection thereof onto a plane that is perpendicular to the thickness direction of the time measuring device overlaps with an orthogonal projection of the indicator needle driving piezoelectric actuator onto the same plane and the antenna is separated from the indicator needle piezoelectric actuator by a prescribed distance in said thickness direction.

Meanwhile, the time measuring device control method is provided with a time indicating process in which time information is indicated by means of a mechanical mechanism using a piezoelectric actuator as a drive source and a communication process executed in parallel with the time indicating process in which communication is conducted with respect to an external communication device through an antenna.

The time measuring device control method is further provided with the following: a receiving process in which time of day information is received from an external source through the antenna once per prescribed period; a current time of day counting process

executed in parallel with the receiving process in which the current time of day information is successively updated based on a time of day corresponding to the time of day information already received; and a time indicating process in which time information is indicated based on the current time of day information by means of a mechanical mechanism using a piezoelectric actuator as a drive source.

[EMBODIMENTS OF THE INVENTION]

Preferred embodiments of the present invention will now be described with reference to the drawings.

[1] First Embodiment

A first embodiment will now be described.

[1.1] Constituent Features of the First Embodiment

Figure 1 is a plan view showing the main components of a time measuring device in accordance with the first embodiment. Figure 2 is a partial cross sectional view (first cross sectional view) of a time measuring device in accordance with the first embodiment. Figure 3 is a partial cross sectional view (second cross sectional view) of a time measuring device in accordance with the first embodiment.

This time measuring device 10 is a wristwatch and is configured to be attached to a user's wrist with a belt that is coupled to the main body of the time measuring device.

The components of the time measuring device 10 can be roughly divided into a receiving circuit unit 11, a power source unit 12, a time measuring unit 13, and an operation unit 14.

The receiving circuit unit 11 is provided with a first receiving quartz oscillator 21 configured to generate a first reference oscillation signal, a second receiving quartz oscillator 22 configured to generate a second reference oscillation signal, a reception processing IC 23 configured to execute reception processing based on the first reference oscillation signal and the second reference oscillation signal, and a coil antenna 24 configured to receive a radio signal transmitted from an external source.

The power source unit 12 is provided with a battery 31 configured to supply electricity and a battery terminal 32 configured and arranged to connect the battery 31 electrically to a circuit board.

The components of the time measuring unit 13 can be roughly divided into the following: a second hand driving piezoelectric actuator 41 for driving an indicator needle that serves as a second hand; a minute-hour hand driving piezoelectric actuator 42 for driving indicator needles that serve as a minute hand and an hour hand; a wheel train 43 for transmitting drive force for driving the indicator needles; a quartz oscillator 44 configured to generate a reference oscillation signal for time measurement; and a time measurement IC

45 configured to execute various time measurement processes based on the reference oscillation signal for time measurement.

Similarly to a typical analog watch, the wheel train 43 is provided with a seconds rotor 51, a seconds rotor pinion 52, an intermediate seconds wheel 53, a seconds wheel 54, a second hand 55, and a seconds rotor pressing member 56. The wheel train 43 is further provided with a minute-hour rotor 61, a minute-hour rotor pinion 62, a first intermediate minute-hour wheel 63, a second intermediate minute-hour wheel 64, a center wheel 65, a minute hand 66, an hour wheel 67, an hour hand 68, a minute wheel 69, and a rotor retainer 70.

The operation unit 14 is provided with a winding stem 71, a first switch 72, a second switch 73, a setting lever 74, and a yoke 75 and is configured such that various settings, e.g. setting and correcting the time, can be accomplished in the same manner as other time measuring devices.

The spatial arrangement of the coil antenna and the second hand driving piezoelectric actuator will now be described with reference to Figure 2 and Figure 3.

In the first embodiment, the coil antenna 24 is arranged in such a position that an orthogonal projection thereof onto a hypothetical plane that is perpendicular to the thickness direction of the time measuring device 10 does not overlap with orthogonal

projections of the second hand driving piezoelectric actuator 41 and the minute-hour hand driving piezoelectric actuator 42 onto the same plane, and the coil antenna 24 is separated from the piezoelectric actuators 41, 42 by a prescribed distance D1 (Figure 3) in a direction perpendicular to said thickness direction.

By arranging the coil antenna 24 in this fashion, the thickness of the time measuring device 10 can be reduced and a thinner wristwatch design can be achieved.

The second hand driving piezoelectric actuator and the minute-hour hand driving piezoelectric actuator will now be described. Only the second hand driving piezoelectric actuator is described in particular because the second hand driving piezoelectric actuator and the minute-hour driving piezoelectric actuator have the same constituent features.

Figure 4 illustrates the constituent features of the second hand driving piezoelectric actuator.

As shown in Figure 4, the second hand driving piezoelectric actuator 41 comprises two plate-like piezoelectric elements 113, 114 arranged so as to sandwich a reinforcing plate 115 made of stainless steel or other material. The reinforcing plate 115 is formed integrally with a fixing part 41A (see Figure 1), an abutting part 41B, and a balance part 41C. The laminated structure helps prevent damage to the piezoelectric elements 113, 114 caused by external forces or by the second hand driving piezoelectric actuator 41 vibrating with an

excessive amplitude.

As shown in Figure 4, electrodes 113A and 114A are arranged on the surfaces of the piezoelectric elements 113 and 114, respectively. Voltage from a drive circuit 200 is supplied to the piezoelectric elements 113, 114 through the electrodes 113A, 114A. If the polarization direction of the piezoelectric element 113 is opposite the polarization direction of the piezoelectric element 114, the piezoelectric elements 113, 114 will elongate and contract when an alternating current drive signal is supplied from the drive circuit 200 such that the electric potential at the top surface, middle, and bottom surface in the figure is +V, -V, +V, respectively (or –V, +V, -V). The +V drive signal and the –V drive signal are alternating current signals whose phases are inverted relative to each other. Consequently, the amplitude of the vibrations that occur in the piezoelectric element 113 above the reinforcing plate 115 and the piezoelectric element 114 below the reinforcing plate 115 can be made larger than in a case where 0 volts is applied to the reinforcing plate 115 (i.e., when the reinforcing plate 115 is connected to the ground of the drive circuit 200). For sake of brevity, Figure 4 shows only the electrodes 113A, 114A positioned on the outside and omits the electric power feeding electrodes that contact the piezoelectric elements 113, 114.

The piezoelectric elements 113, 114 are made of such materials as lead zirconate titanate, quartz crystal, lithium niobate, barium titanate, lead titanate, lead meta-niobate,

polyvinylidene fluoride, lead zinc niobate, and lead scandium niobate.

The operation of the second hand driving piezoelectric actuator 41 will now be described.

When the drive circuit 200 applies an alternating current drive signal to the piezoelectric elements 113, 114 through the electrodes 113A, 114A, the piezoelectric elements 113, 114 vibrate by elongating and contracting in the lengthwise direction. This longitudinal vibration, i.e., lengthwise elongation and contraction, is indicated by the arrows in Figure 5. When the second hand driving piezoelectric actuator 41 is electrically excited by applying a drive signal to the piezoelectric elements 113, 114 and thereby undergoes longitudinal vibration, a rotational moment is generated about the center of gravity of the second hand driving piezoelectric actuator 41 due to the unbalanced state of the weight balance of the piezoelectric actuator 41. As shown in Figure 6, the rotational moment causes the second hand driving piezoelectric actuator 41 to undergo a secondary bending vibration in which it undulates in the widthwise direction. Since a balance part 41C (Figure 2) is provided on the opposite end of the second hand driving piezoelectric actuator 41 as the abutting part 41B, a larger bending vibration can be induced and a larger rotational moment can be generated.

In this way, the second hand driving piezoelectric actuator 41 undergoes both a

longitudinal vibration and a bending vibration and the combination of the longitudinal vibration and bending vibration causes the contacting portions of the seconds rotor 51 and the abutting part 41B of the second hand driving piezoelectric actuator 41 to move along an elliptical path as shown in Figure 7. Since the abutting part 41B moves clockwise along the elliptical path, the force with which the abutting part 41B presses against the seconds rotor 51 is larger when the abutting part 41B is in a position where it is expanded toward the seconds rotor 51 and the force with which the abutting part 41B presses against the seconds rotor 51 is smaller when the abutting part 41B is in a position where it is retracted from the seconds rotor 51. Thus, when the pressing force between the two is large, i.e., when the abutting part 41B is in a position where it is expanded toward the seconds rotor 51, the seconds rotor 51 is rotationally driven in the direction of the displacement of the abutting part 41B.

In short, the second hand driving piezoelectric actuator 41 rotationally drives the seconds rotor 51 by means of an elliptical motion resulting from the combination of a longitudinal vibration and a bending vibration. The seconds rotor 51 is pressed against the abutting part of the second hand driving actuator by the seconds rotor pressing member 56 and thus is rotationally driven in a reliable manner.

When the seconds rotor 51 is rotationally driven, the seconds rotor pinion 52 rotates and

rotationally drives the intermediate seconds wheel 53 that meshes therewith.

In turn, the intermediate seconds wheel 53 rotates the seconds wheel 54 that meshes therewith and causes the second hand 55 fixed to the seconds wheel 54 to rotate.

Meanwhile, the minute-hour hand driving piezoelectric actuator 42 rotationally drives the minute-hour rotor 61 by means of an elliptical motion resulting from the combination of a longitudinal vibration and a bending vibration. The minute-hour rotor 61 is pressed against the abutting part of the minute-hour hand driving piezoelectric actuator by the minute-hour rotor pressing member 62 and, thus, is rotationally driven in a reliable manner.

When the minute-hour rotor 61 is rotationally driven, the minute-hour rotor pinion 62 rotates and rotationally drives the first intermediate minute-hour wheel 63 that meshes therewith.

In turn, the first intermediate minute-hour wheel 63 rotationally drives the second intermediate minute-hour wheel 64 that meshes therewith.

The second intermediate minute-hour wheel 64 meshes with the center wheel 65 and also drives the minute wheel 69 through the center wheel 65. As a result, the minute hand 66 fixed to the center wheel 65 and the hour hand 68 fixed to the hour wheel 67 are rotated.

The operation of the receiving circuit unit 11 will now be described.

The first receiving quartz oscillator 21 of the receiving circuit unit 11 is configured to

generate a first reference oscillation signal corresponding to a standard low frequency radio signal (40 kHz in Japan) and output the first reference oscillation signal to the reception processing IC 23. Similarly, the second receiving quartz oscillator 22 is configured to generate a second reference oscillation signal corresponding to a 60-kHz standard low frequency radio signal and output the second reference oscillation signal to the reception processing IC 23.

Simultaneously, the coil antenna 24 (e.g., a ferrite antenna) receives the standard low frequency radio signal carrying the time of day data.

The reception processing IC 23 demodulates the standard low frequency radio signal received by the coil antenna 24 into time of day data, stores the time of day data, and notifies the time measurement IC.

The reception processing IC 23 comprises an automatic gain control (AGC) circuit, an amplification circuit, a band pass filter, a demodulation circuit, and a decoder circuit.

The amplification circuit of the reception processing IC 23 amplifies the standard low frequency radio signal received by the coil antenna 24 under the gain control of the AGC circuit and feeds the amplified signal to the band pass filter.

The band pass filter extracts a prescribed frequency component from the amplified standard low frequency radio signal and feeds the extracted component to the demodulation

circuit.

The demodulation circuit smoothes and demodulates the prescribed frequency component of the standard low frequency radio signal and feeds the resulting demodulated signal to the decoder circuit.

The decoder circuit decodes the demodulated standard low frequency radio signal and outputs the result as a receiving circuit output signal.

Meanwhile, the AGC circuit executes gain control with respect to the amplification circuit based on the output signal of the demodulation circuit and thereby controls the reception of the standard low frequency radio signal to a constant reception level.

The reception processing IC 23 receives a power saving mode signal for executing control to reduce the power consumption from the time measuring IC 45. This signal serves to turn the reception operation of the reception processing IC 23 off when it is not necessary.

Normally, the reception processing IC 23 is controlled by the power saving mode signal such that it receives the standard low frequency radio signal approximately once per day. If the time of day data cannot be received properly, the reception operation is repeated a plurality of times.

In this embodiment, electromagnetic noise does not occur because piezoelectric

actuators are used to drive the hands (indicator needles) of the timepiece. Consequently, the driving of the hands does not affect the reception of the standard low frequency radio signal. As a result, the reception operation of the receiving circuit unit 11 can be executed in parallel (simultaneously) with the hand driving operation of the time measuring unit 13.

Thus, with the first embodiment, the standard low frequency radio signal can be received and the indicated time of day corrected at any time. Moreover, there is no need to provide a control process and circuit for preventing the hands from being driven during reception of the standard low frequency radio signal. As a result, the control processes and circuitry can be simplified.

[2] Second Embodiment

In the first embodiment, the coil antenna 24 is arranged in such a position that an orthogonal projection thereof onto a hypothetical plane that is perpendicular to the thickness direction of the time measuring device 10 (i.e., a plane perpendicular to the plane of the paper) does not overlap with an orthogonal projection of the second hand driving piezoelectric actuator 41 onto the same plane, and the coil antenna 24 is separated from the piezoelectric actuator 41 by a prescribed distance in a direction perpendicular to said thickness direction.

Conversely, in the second embodiment, the coil antenna is arranged in such a position

that at least a portion of an orthogonal projection thereof onto a plane that is perpendicular to the thickness direction of the time measuring device overlaps with an orthogonal projection of at least one of the piezoelectric actuators, i.e., the second hand driving piezoelectric actuator and/or the minute-hour hand driving piezoelectric actuator, onto the same plane, and the coil antenna is separated from the piezoelectric actuator(s) by a prescribed distance in said thickness direction.

Figure 8 shows a partial cross sectional view of a time measuring device in accordance with the second embodiment. In Figure 8, parts that are identical to the parts shown in Figures 2 and 3 are indicated with the same reference numerals.

The coil antenna 24 is arranged in such a position that at least a portion of an orthogonal projection thereof onto a hypothetical plane that is perpendicular to the thickness direction of the time measuring device 10 overlaps with an orthogonal projection of the second hand driving piezoelectric actuator 41 onto the same plane, and the coil antenna 24 is separated from the piezoelectric actuator 41 by a prescribed distance D2 in said thickness direction.

With this arrangement, the size of the time measuring device can be reduced.

Additionally, similarly to the first embodiment, the standard low frequency radio signal can be received and the indicated time of day corrected at any time. Moreover, there is no need to provide a control process and circuit for preventing the hands from being driven

during reception of the standard low frequency radio signal. As a result, the control processes and circuitry can be simplified.

Although the present invention has been explained heretofore based on the embodiments, the invention is not limited to these embodiments.

While the rotor is driven in only one direction in the embodiments, it is also possible to configure the device such that the rotor can be driven in both the forward and reverse directions. Figure 9 shows the electrode arrangement of a piezoelectric actuator (second hand driving piezoelectric actuator or minute-hour hand driving piezoelectric actuator) configured such that it can drive in both the forward and reverse directions.

As shown in Figure 9, this alternative piezoelectric actuator 400 is provided with a central electrode 401 and two electrode pairs 402, 403, each arranged diagonally across from each other relative to the central electrode 401.

With this arrangement, an elliptical drive oriented in a first direction (forward direction) is obtained by applying a drive voltage to the central electrode 401 and the electrode pair 402 and not applying the drive voltage to the electrode pair 403.

As a result, a longitudinal vibration is driven by the central electrode 401 and a secondary bending vibration corresponding to the first direction are caused by the unbalanced state of the longitudinal vibration (elongations and contractions) of the

piezoelectric elements resulting from applying the drive voltage to the electrode pair 402 and not to the electrode pair 403.

The combination of the longitudinal vibration and the secondary bending vibration produces elliptical vibration in the first direction.

Conversely, an elliptical drive oriented in a second direction (reverse direction) is obtained by applying a drive voltage to the central electrode 401 and the electrode pair 403 and not applying the drive voltage to the electrode pair 402.

As a result, a longitudinal vibration is driven by the central electrode 401 and a secondary bending vibration corresponding to the second direction are caused by the unbalanced state of the longitudinal vibration (elongations and contractions) of the piezoelectric elements resulting from applying the drive voltage to the electrode pair 403 and not to the electrode pair 402.

The combination of the longitudinal vibration and the secondary bending vibration produces elliptical vibration in the second direction.

In both of these cases, it is preferred to use the electrode pair to which the drive voltage is not applied as detection electrodes for detecting the state of the vibration. More specifically, the piezoelectric elements emit heat as a result of the vibration and the change in temperature causes the Young's modulus and other properties to change. Therefore,

instead of driving the vibration using a fixed resonance frequency, it is preferable to use the electrode pair to which the drive voltage is not applied to detect the voltage generated due to the vibration and control the drive frequency by adjusting the phase difference and the absolute value of the voltage to prescribed control target values.

Figure 10 shows electrode arrangement of another piezoelectric actuator configured such that it can drive in both the forward and reverse directions.

While the previous alternative piezoelectric actuator has a central electrode 401 and two electrode pairs 402, 403, this alternative piezoelectric actuator 400A has only two electrode pairs 402, 403 and omits the central electrode 401, as shown in Figure 11.

With this arrangement, an elliptical drive oriented in a first direction (forward direction) is obtained by applying a drive voltage to the electrode pair 402 and not applying a drive voltage to the electrode pair 403. As a result, the drive voltage applied to the electrode pair 402 causes the piezoelectric elements to undergo longitudinal vibration and the unbalanced state of the elongations and contractions of the piezoelectric elements causes a secondary bending vibration corresponding to the first direction to occur.

The combination of the longitudinal vibration and the secondary bending vibration produces elliptical vibration in the first direction.

Conversely, an elliptical drive oriented in a second direction (reverse direction) is

obtained by applying a drive voltage to the electrode pair 403 and not applying the drive voltage to the electrode pair 402.

As a result, the drive voltage applied to the electrode pair 403 causes the piezoelectric elements to undergo longitudinal vibration and the unbalanced state of the elongations and contractions of the piezoelectric elements causes a secondary bending vibration corresponding to the second direction to occur.

The combination of the longitudinal vibration and the secondary bending vibration produces elliptical vibration in the second direction.

In both of these cases, for the same reasons as for the previous alternative piezoelectric actuator, it is preferred to use the electrode pair to which the drive voltage is not applied as detection electrodes for detecting the state of the vibration.

Figure 11 shows the electrode arrangement of still another piezoelectric actuator.

While the previously described alternative piezoelectric actuators are provided with a plurality of electrodes, this alternative piezoelectric actuator 400B is provided with a single full-surface electrode 404, as shown in Figure 12.

Additionally, instead of the abutting part 341B, the vibrating body 341 of this alternative piezoelectric actuator is provided with abutting parts 341B1, 341B2 in unbalanced positions. As a result, longitudinal and bending vibrations are produced due to

the mechanically unbalanced state of the vibrating body 341.

Although this alternative piezoelectric actuator is provided with two abutting parts 341B1, 341B2, it is also feasible to provide only one abutting part.

Figure 12 shows the electrode arrangement of still another piezoelectric actuator.

While the alternative piezoelectric actuator shown in Figure 11 has a full-surface electrode 404, this alternative piezoelectric actuator 400C has a drive electrode 405 arranged so as to join the abutting parts 341B1, 341B2 together and a detection electrode pair 406, as shown in Figure 12.

With this arrangement, when a drive voltage is applied to the drive electrode 405 the piezoelectric elements are excited so as to undergo a longitudinal vibration and the elongation and contraction of the piezoelectric elements are unbalanced. Additionally, the mechanically unbalanced state of the abutting parts 341B1, 341B2 causes secondary bending vibration to occur in a reliable fashion.

The combination of the longitudinal vibration and the secondary bending vibration produces an elliptical vibration.

Meanwhile, for the same reasons as described regarding a previous alternative piezoelectric actuator, the piezoelectric actuator can be controlled more accurately by using the detection electrode pair 406 as detection electrodes for detecting the vibration state of

the actuator.

Although the support positions of the piezoelectric actuator are not described in detail in the preceding explanations, vibration losses can be reduced by supporting the piezoelectric actuator in the middle portion thereof, which corresponds to nodes of both the longitudinal vibration and the secondary bending vibration.

[5] Variations of the Embodiments

Although in the embodiments described heretofore the communication unit is a receiver device configured to receive a low frequency radio signal, it is also possible for the communication unit to be a wireless communication device configured to both receive and transmit.

Although the embodiments described heretofore are provided with a second hand driving piezoelectric actuator and a minute-hour hand driving piezoelectric actuator, it is also possible to drive the second hand, the minute hand, and the hour hand with three separate piezoelectric actuators or to drive the second hand, the minute hand, and the hour hand with one piezoelectric actuator.

Although in the embodiments described heretofore a ferrite antenna 24 configured to receive a standard low frequency radio signalcarrying time of day information is used, it is also acceptable to use a loop antenna or a ferrite antenna if an FM multiplex broadcasting

signal (76 MHz to 108 MHz) carrying time of day information is to be received or a microstrip antenna or a helical antenna if a radio signal (1.5 GHz) carrying time of day information from a GPS satellite is to be received.

Although in the embodiments described heretofore the indicated hour, minute, and second are corrected automatically based on a standard low frequency radio signal carrying time of day information, it is also acceptable to correct an indicated date automatically. More specifically, since the standard low frequency radio signal contains date information, the indicated date can be corrected automatically based on the standard low frequency radio signal if a piezoelectric actuator for driving a calendar indicator is provided in addition to piezoelectric actuators for driving the hour hand, minute hand, and second hand. In such a case, it is also acceptable to add a device for detecting the position of the calendar indicator.

Although the embodiments described heretofore are configured to receive a standard low frequency radio signal as the radio signal carrying the time of day information, it is also feasible to configure the time measuring device to receive a GPS signal, a FLEX-TD pager signal, an FM multiplex broadcast signal, a CDMA signal, or other type of signal instead of a standard low frequency radio signal.

[EFFECTS OF THE INVENTION]

Since the present invention uses a piezoelectric actuator(s) as the drive source for the

time indicating unit, the time indicating operation and the communication operation can be executed simultaneously without the drive source of the time indicating unit affecting the communication processing occurring between the communication unit and the external communication device through the antenna.

Moreover, there is no need to provide a control process and circuit for preventing the time indicating operation from being executed during execution of the communication operation. As a result, the control processes and circuitry can be simplified.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Figure 1 is a plan view showing the main components of a time measuring device in accordance with the first embodiment.

Figure 2 is a partial cross sectional view (first cross sectional view) of a time measuring device in accordance with the first embodiment.

Figure 3 is a partial cross sectional view (second cross sectional view) of a time measuring device in accordance with the first embodiment.

Figure 4 illustrates the constituent features of the second hand driving piezoelectric actuator.

Figure 5 is a side view of the piezoelectric actuator.

Figure 6 is a top plan view of the piezoelectric actuator.

Figure 7 is an enlarged view of the abutting part of the piezoelectric actuator.

Figure 8 is a partial cross sectional view of a time measuring device in accordance with the second embodiment.

Figure 9 shows the electrode arrangement of a piezoelectric actuator configured such that it can drive in both the forward and reverse directions.

Figure 10 shows the electrode arrangement of a piezoelectric actuator configured such that it can drive in both the forward and reverse directions.

Figure 11 shows the electrode arrangement of another piezoelectric actuator.

Figure 12 shows the electrode arrangement of still another piezoelectric actuator.

[DESCRIPTIONS OF THE REFERENCE SYMBOLS]

10 time measuring device, 11 receiving circuit unit, 12 power source unit, 13 time measuring unit, 14 operation unit, 21 first receiving quartz oscillator, 22 second receiving quartz oscillator, 23 reception processing IC, 24 coil antenna, 31 battery, 32 battery terminal, 41 second hand driving piezoelectric actuator (indicator needle driving piezoelectric actuator), 42 minute-hour hand driving piezoelectric actuator (indicator needle driving piezoelectric actuator), 44 reference oscillation signal generating quartz oscillator, 45 time measuring IC

[Document Type] Abstract

[Abstract]

[OBJECT] To provide a time measuring device that has simpler circuitry and can indicate the time of day accurately even while receiving a standard low frequency radio signal, and to provide a control method for such a time measuring device.

[CONSTITUTION] A communication circuit unit 11 receives time of day information from an external source through an antenna once per prescribed period and a time measuring unit 13 updates the current time of day information successively based on a time of day corresponding to the time of day information received by the communication circuit unit 11. Either in parallel with or independently of the receiving operation of the receiving circuit unit 11, the time measuring unit 13 indicates time information based on the current time of day information by means of a mechanical mechanism using a second hand driving piezoelectric actuator 41 and a minute-hour hand driving piezoelectric actuator 42 as drive sources.

[Selected Drawing] Figure 1